

a series of experiments on bones, he comes to the conclusion, that oxalic acid is the solvent for the phosphates in the animal œconomy; and deduces the production of oxalic acid, and especially of its hypernormal quantities,—first, from a hypernormal quantity of non-nitrogenous food, such as sugar, starch and farinaceous substances; and secondly, from want of sufficient oxygen taken from the air, as in malarious situations, or in the cases of persons suffering from disease of the lungs. The results of the author's observations are finally summed up in the following terms:—

1. That in the human œconomy, as well as in plants and in the inferior animals, the production of cells indispensably requires the presence of phosphate of lime.

2. That a deficient formation of cells in morbid affections of the system almost invariably indicates a deficiency of phosphate of lime; and that the administration of phosphate of lime has proved most beneficial in such affections.

3. That this deficiency of phosphate of lime is proved really to exist by the hypernormal quantities of phosphates eliminated by the urine in almost all the cases in which a deficient formation of cells or a want of flesh exists.

4. That this elimination of phosphates is caused by the oxalic acid which is produced in the œconomy in health as well as in disease, and causes the elimination as well of the normal as of the hypernormal quantities of the phosphates.

5. That the production of oxalic acid in preternatural quantities depends on different causes, the principal of which are,—the use of abundant quantities of saccharine and farinaceous food; the want of sufficient reception of oxygen by the lungs; a morbid decomposition of uric acid into urea and oxalic acid; and very probably the presence of abundant quantities of alkali in the blood.

6. That, consequently, by putting a stop to the production of hypernormal quantities of oxalic acid, we shall stop the elimination of hypernormal quantities of the phosphates, and consequently promote the formation of cells, supposing a sufficient quantity of nitrogenous and non-nitrogenous substances to be present.

11. "Supplementary Observations on the Diffusion of Liquids." By Thomas Graham, Esq., F.R.S., F.C.S.

The former experiments of the author furnished strong grounds for believing that isomorphous salts possess a similar diffusibility. All the salts of potash and ammonia, which were compared, appear to be equi-diffusive; so also were the salts of certain magnesian bases. A single preliminary observation on the nitrates of lead and baryta, however, opposed the general conclusion, and demanded further inquiry. It is scarcely necessary to say that any new means of recognizing the existence of the isomorphous relation between different substances, must prove highly valuable. The investigation was also extended to several new substances, such as hydrocyanic acid, acetic acid, sulphurous acid, alcohol, ammonia and salts of organic bases, without reference to isomorphous relations.

*Hydrogen Acids.*—The period of diffusion arbitrarily chosen for these acids was five days. The diffusate, or quantity of acid diffused, was determined by precipitating the liquid of the external reservoirs with nitrate of silver, and weighing the salt of silver formed.

Diffusion of hydrochloric acid in five days, at 51° F., in two cells:—

	Grs.	Ratio.
From 1 per cent. solution . . . . .	7·41	0·97
From 2 per cent. solution . . . . .	15·04	2·00
From 4 per cent. solution . . . . .	30·72	4·08
From 8 per cent. solution . . . . .	67·68	9·00

Hydrochloric acid is the most highly diffusive substance hitherto observed; it appears to exceed hydrate of potash at 53°·5, as 7·56 to 6·12, or as 100 to 80·9.

The experiments indicate a similarity of diffusion between the isomorphous substances, hydrochloric and hydriodic acids, and hydrochloric and hydrobromic acids.

Diffusate from 2 per cent. solutions at 51° F.:—

Hydrochloric acid . . . . .	15·04	100
Hydriodic acid. . . . .	15·11	100·46

Diffusate from 2 per cent. solutions at 59°·7 F.:—

Hydrochloric acid . . . . .	16·55	100
Hydrobromic acid . . . . .	16·58	100·18

Hydrobromic acid appears therefore to coincide in diffusibility with hydrochloric acid at this temperature. It is remarked that these three acids, hydrochloric, hydrobromic and hydriodic, do not exhibit the same correspondence in another physical property, namely, the densities of their aqueous solutions containing the same proportion of acid. The densities of 2 per cent. solutions of hydrochloric and hydriodic acids appear to be respectively 1·0104 and 1·0143, at 60° F., and that of hydrobromic acid is an intermediate number. The same acids are also known to differ considerably in the boiling-points of solutions containing the same proportion of acid. A considerable diversity of physical properties appears here to be compatible with equal diffusibility in substances which are isomorphous.

The diffusion-time of bromine was made ten days, or double the time of hydrobromic acid. Two cells contained together a diffusate of 5·80 grs. of bromine; another two cells a diffusate of 5·88 grs.; mean 5·84 grs. at 60°·1 F.; or 6·76 grs. for a 1 per cent. solution. Doubling the last result, 13·52 grs. are obtained for a 2 per cent. solution, which is still considerably under the diffusate of hydrobromic acid (16·58 grs.) in half the time.

Hydrocyanic acid appeared less diffusive than hydrochloric acid, at the same temperature 59°·7, as 12·45 to 16·55, or as 75·2 to 100, and not to belong therefore to the same class of diffusive substances.

*Nitric Acid.*—Time of diffusion also five days. The quantity of

this acid diffused was determined with great exactness by neutralization by means of a normal solution of carbonate of soda.

The diffusion of the different proportions of this acid at one temperature is as follows.

Diffusion of nitrate of water in five days at  $51^{\circ}2$ ; two cells:—

	Grs.	Ratio.
From 1 per cent. solution .....	6.99	0.95
From 2 per cent. solution .....	14.74	2
From 4 per cent. solution .....	28.76	3.90
From 8 per cent. solution .....	57.92	7.86

The 2 per cent. solution is taken as the standard of comparison for the ratios, instead of the 1 per cent. solution, from the greater accuracy with which the diffusion of the former can be observed.

The usual approach to equality of diffusion, between chlorides and nitrates, is observable in hydrochloric and nitric acids, at least in the 1 and 2 per cent. solutions.

*Sulphuric Acid.*—The time of diffusion arbitrarily chosen for this and the three following acids was ten days. The diffusate of this acid was determined in the same manner as that of nitric acid.

The diffusion of the different proportions of sulphuric acid is as follows.

Diffusion of sulphate of water in ten days at  $49^{\circ}7$ ; two cells:—

	Grs.	Ratio.
From 1 per cent. solution .....	8.69	1.03
From 2 per cent. solution .....	16.91	2
From 4 per cent. solution .....	33.89	4.01
From 8 per cent. solution .....	68.96	8.16

The diffusibility of different strengths of this acid appears to be pretty uniform, but with a slight tendency to increase in the higher proportions, like hydrochloric acid.

Sulphuric acid is greatly inferior in velocity of diffusion to hydrochloric acid, but still appears to possess considerably more than half the diffusibility of the latter.

*Chromic Acid.*—The diffusate of the 2 per cent. solution was 22.43 grs. of chromic acid, in two cells, at  $67^{\circ}3$ . The diffusion of sulphuric acid at  $63^{\circ}5$ , was 19.73 grs., which would give about 21 grs. of that acid at  $67^{\circ}3$ .

*Acetic Acid.*—This acid cannot be determined accurately by the acidimetric method, owing to the acetates of potash and soda being essentially alkaline to test-paper, like the carbonates of the same bases, although neutral in composition. The weight of carbonate of baryta dissolved by the acid was had recourse to.

Diffusion of acetate of water in ten days at  $48^{\circ}8$ ; two cells:—

	Grs.	Ratio.
From 2 per cent. solution .....	11.31	2
From 4 per cent. solution .....	22.02	3.83
From 8 per cent. solution .....	41.80	7.26

The diffusibility diminishes with the larger proportions of acid.

This acid appears to be considerably less diffusive than sulphuric acid.

*Sulphurous Acid*.—Diffusion of sulphurous acid in ten days at 68°·1; two cells:—

	Grs.	Ratio.
From 1 per cent. solution . . . . .	8·09	0·954
From 2 per cent. solution . . . . .	16·96	2
From 4 per cent. solution . . . . .	33·00	3·891
From 8 per cent. solution . . . . .	66·38	7·827

This substance appears to be less diffusive than sulphuric acid at the same temperature; the diffusion of sulphurous acid at 68°·1 considerably resembles that of sulphuric acid at 49°·7.

*Ammonia*.—Diffusion of ammonia in 4·04 days, the time of hydrate of potash, at 63°·4; two cells:—

	Grs.	Ratio.
From 1 per cent. solution . . . . .	4·93	1·029
From 2 per cent. solution . . . . .	9·59	2
From 4 per cent. solution . . . . .	19·72	4·117
From 8 per cent. solution . . . . .	41·22	8·605

Ammonia appears to have a diffusibility approaching to that of hydrate of potash. It appears very similar to hydrocyanic acid at the same temperature; or to possess about three-fourths of the diffusibility of hydrochloric acid.

*Alcohol*.—Time of diffusion ten days. The quantity of alcohol diffused was determined by careful distillation. The density of the alcohol solutions in the phials was always made to exceed that of the water in the jars, by the addition of chloride of sodium to the former.

Diffusion of alcohol in ten days at 48°·7; two cells:—

From 2 per cent. solution . . . . .	8·62
From 4 per cent. solution . . . . .	16·12
From 8 per cent. solution . . . . .	35·50

Alcohol does not appear to belong to the same class of diffusive substances as acetic acid, which might be expected from their similarity of composition, but possesses a considerably lower diffusibility.

Diffusion from 2 per cent. solutions in ten days:—

Acetate of water at 48°·8 . . . . .	11·51	100
Alcohol at 48°·7 . . . . .	8·62	74·9

The diffusion of alcohol approaches to one-half of that of sulphate of water at nearly the same temperature.

Alcohol may be substituted for water to dissolve certain salts, and at the same time be made an atmosphere into which these salts are allowed to diffuse. From experiments which have been commenced on this subject, it appears that the diffusion of hydrate of potash, iodide of potassium, chloride of calcium and others is about four times slower into alcohol of density 0·840 than into water. The salts likewise often exhibit the same relations in their diffusibility in alco-

hol, as in water, with some singular exceptions, such as chloride of mercury.

*Nitrate of Baryta.*—The time of diffusion of this and the two following nitrates was 11·43 days\*. The salt diffused was precipitated by sulphuric acid, and calculated from the weight of the sulphate of baryta formed.

Diffusion of nitrate of baryta in 11·43 days at 64°·1; two cells:—

	Grs.	Ratio.
From 1 per cent. solution . . . . .	7·72	1·026
From 2 per cent. solution . . . . .	15·04	2
From 4 per cent. solution . . . . .	29·60	3·936
From 8 per cent. solution . . . . .	54·50	7·247

The diffusion of nitrate of strontia almost coincides with that of the isomorphous nitrate of baryta at the same temperature.

Diffusion from 1 per cent. solutions at 51°·5 in 11·43 days:—

Nitrate of baryta . . . . .	6·73	100
Nitrate of strontia . . . . .	6·79	100·89

*Nitrate of Lime.*—The diffusate was evaporated to dryness with an excess of sulphuric acid, and the nitrate of lime, which is always supposed anhydrous, was estimated from the sulphate of lime produced.

Diffusion of nitrate of lime in 11·43 days at 64°·1; two cells:—

	Grs.	Ratio.
From 1 per cent. solution . . . . .	7·66	1·021
From 2 per cent. solution . . . . .	15·01	2
From 4 per cent. solution . . . . .	29·04	3·872
From 8 per cent. solution . . . . .	55·10	7·334

The results throughout for this salt are almost identical with those of nitrate of baryta, although these two salts differ greatly in solubility, and in one being a hydrated, and the other an anhydrous salt.

*Acetates of Lead and Baryta.*—Diffused for 16·166 days; the time chosen before for sulphate of magnesia, with seven days for chloride of sodium. These salts were diffused into water slightly acidulated with acetic acid.

Diffusion of 1 per cent. solutions in 16·166 days; two cells:—

Acetate of baryta at 53°·5 . . . . .	7·50	100
Acetate of lead at 53°·1 . . . . .	7·84	104·53

Here, of two isomorphous salts, that of greatest atomic weight sensibly exceeds the other in diffusibility.

*Chlorides of Barium and Strontium.*—The diffusion of these salts being manifestly more rapid than that of the chloride of calcium, a shorter time was tried, which is to seven days, the time of chloride of sodium, as the square root of 3 to the square root of 4·5.

\* This time is to that of sulphate of magnesia (16·166 days) as the square root of 8 is to the square root of 16; but does not appear to express the true relation between these salts.

Diffusion of chloride of barium in 8·57 days at 63°; two cells:—

	Grs.	Ratio.
From 1 per cent. solution . . . . .	6·32	1·047
From 2 per cent. solution . . . . .	12·07	2
From 4 per cent. solution . . . . .	23·96	3·970
From 8 per cent. solution . . . . .	45·92	7·608

Diffusion of chloride of strontium in 8·57 days at 63°; 2 cells:—

	Grs.	Ratio.
From 1 per cent. solution . . . . .	6·09	1·045
From 2 per cent. solution . . . . .	11·66	2
From 4 per cent. solution . . . . .	23·56	4·041
From 8 per cent. solution . . . . .	44·46	7·626

Both the diffusates and ratios in the preceding table correspond closely with those of chloride of barium.

*Chloride of Calcium.*—The time for this and all the following magnesian chlorides and nitrates was 11·43 days.

Diffusion of chloride of calcium in 11·43 days at 63°·8; two cells:—

	Grs.	Ratio.
From 1 per cent. solution . . . . .	7·92	1·032
From 2 per cent. solution . . . . .	15·35	2
From 4 per cent. solution . . . . .	30·78	4·010
From 8 per cent. solution . . . . .	61·56	8·021

On comparing solutions of chloride of calcium and nitrate of lime, it appears that the correspondence between the 1 and 2 per cent. solutions is sufficiently close, but that in the 4 and 8 per cent. the salts diverge, as happens also with hydrochloric and nitric acids themselves. The nitrate in both cases falls off, while the chloride sustains throughout the high diffusibility of the lower proportions.

Comparing certain other salts with chloride of calcium diffused at the same temperature, 50°·8, the following are the results:—

Chloride of calcium . . . . .	6·51	100
Chloride of manganese . . . . .	6·63	101·85
Nitrate of magnesia . . . . .	6·49	99·69
Nitrate of copper . . . . .	6·44	98·92

The following additional magnesian chlorides do not exhibit so close a correspondence as the preceding:—

Chloride of calcium . . . . .	6·51	100
Chloride of zinc . . . . .	6·29	96·61
Chloride of magnesium . . . . .	6·17	94·77
Protosulphate of iron . . . . .	6·15	94·73
Chloride of copper . . . . .	6·06	93·08

*Sesquichloride of Iron.*—A series of observations was made upon the diffusion of the different proportions of this salt from 1 to 8 per cent., but in all of them decomposition was determined by the diffusion, with turbidity also in the solution phial except in the 8 per cent. solution.

The mean diffusion from the 8 per cent. solution, at 63°·3, was

55·88 grs. of sesquichloride of iron, with 6·66 grs. of free hydrochloric acid, in two cells. It appears from this that perchloride of iron approaches the chloride of calcium in diffusibility. That the proto- and persalts of the magnesian metals should have a similar rate of diffusion, is not unlikely from other analogies which they exhibit.

*Sulphates of Magnesia and Zinc.*—The time chosen for the diffusion of these salts, namely, 16·166 days, is a multiple by 2 of the time of sulphate of potash, and by 4 of the time of hydrate of potash. The diffusate was evaporated to dryness and weighed.

Diffusion of sulphate of magnesia in 16·16 days at 65°·4; two cells:—

	Grs.	Ratio.
From 1 per cent. solution . . . . .	7·31	1·144
From 2 per cent. solution . . . . .	12·79	2
From 4 per cent. solution . . . . .	23·46	3·671
From 8 per cent. solution . . . . .	42·82	6·701
From 8 per cent. solution at 62°·8. .	42·66	1
From 16 per cent. solution at 62°·8. .	75·06	1·759
From 24 per cent. solution at 62°·8. .	102·04	2·340

Diffusion of sulphate of zinc in 16·16 days at 65°·4; two cells:—

	Grs.	Ratio.
From 1 per cent. solution . . . . .	6·67	1·091
From 2 per cent. solution . . . . .	12·22	2
From 4 per cent. solution . . . . .	23·12	3·784
From 8 per cent. solution . . . . .	42·26	6·916
From 8 per cent. solution at 62°·8. .	39·62	1
From 16 per cent. solution at 62°·8. .	74·40	1·878
From 24 per cent. solution at 62°·8. .	101·42	2·560

It is remarked that the diffusion of these two isomorphous salts, sulphate of magnesia and sulphate of zinc, differs so much, in the 1 per cent. solution, as 8·75 per cent. This, however, is considered to be an accidental error, the disturbances from changes of temperature and other causes of dispersion being in direct proportion to the duration of the experiment, and therefore much increased with long times; while the 1 per cent. solution also, from its low density, is the proportion most exposed to such errors. The sulphate of zinc appears to be the truest throughout, in its diffusion, of these two salts. The approach to equality becomes close in the 4 per cent. and larger proportions of salt, particularly with the unusually high proportions of 16 and 24 per cent., which were observed in these salts. The diffusion of both salts falls off remarkably in the higher proportions. The result of the comparison of these two magnesian sulphates is no doubt favourable to the similarity of diffusion of isomorphous salts.

*Sulphate of Alumina.*—The time of diffusion was the same as that for sulphate of magnesia.

Diffusion of sulphate of alumina in 16·166 days at 65°·4; two cells:—

	Grs.	Ratio.
From 1 per cent. solution . . . . .	5.48	1.074
From 2 per cent. solution . . . . .	10.21	2
From 4 per cent. solution . . . . .	19.28	3.780
From 8 per cent. solution . . . . .	33.52	6.572

The diffusion of sulphate of alumina is very sensibly less than that of sulphate of zinc at the same temperature.

*Nitrates of Silver and Soda and Chloride of Sodium.*—Time of diffusion seven days.

Diffusion of nitrate of silver for seven days at 63°4; two cells:—

	Grs.	Ratio.
From 2 per cent. solution . . . . .	13.61	2
From 4 per cent. solution . . . . .	26.34	3.87
From 8 per cent. solution . . . . .	51.88	7.62

Diffusion of chloride of sodium and nitrate of soda in seven days, both at 63°4; two cells:—

Chloride of sodium, 2 per cent. . .	12.37	100
Nitrate of soda, 2 per cent. . . . .	12.35	99.83
Chloride of sodium, 4 per cent. . .	24.96	100
Nitrate of soda, 4 per cent. . . . .	23.58	94.48
Chloride of sodium, 8 per cent. . .	48.44	100
Nitrate of soda, 8 per cent. . . . .	47.74	98.55

As usual, the chloride is slightly more rapid in its diffusion than the nitrate.

*Chlorides, Iodides and Bromides of Potassium and Sodium.*—Time of diffusion 5.71 days. The salt diffused was treated with nitrate of silver, and the chloride of silver weighed.

Diffusion of chloride of potassium in 5.71 days at 62°; two cells:—

	Grs.	Ratio.
From 1 per cent. solution . . . . .	6.69	1.005
From 2 per cent. solution . . . . .	13.32	2
From 4 per cent. solution . . . . .	25.94	3.895
From 8 per cent. solution . . . . .	53.64	8.054

The ratios are in remarkably close accordance with the proportions of salt diffused.

The times 5.71 and seven days chosen for the chloride of potassium and sodium, it will be observed, are as the square roots of 2 and 3. A certain deviation from this ratio of the times of equal diffusion, appears on comparing the experimental results obtained at present for these salts.

The following is the result of the diffusion of three isomorphous salts of potassium.

Diffusion of 2 per cent. solutions in 5.716 days, at 59°8:—

	Grs.	Ratio.
Chloride of potassium . . . . .	12.24	100
Bromide of potassium . . . . .	12.46	101.80
Iodide of potassium . . . . .	12.51	102.21

Mean. . . . . 12.40

The corresponding salts of sodium were also compared.



Diffusion of 2 per cent. solutions for seven days :—

	Grs.	Ratio.
Chloride of sodium at 60° . . . . .	12·14	100
Bromide of sodium at 59°·8 . . . .	11·93	98·27
Iodide of sodium at 59°·8 . . . . .	12·18	100·33
Mean . . . . .	12·08	

In both groups there is a near approach to equality of diffusion. The times for the salts of the two bases being in the empirical proportion of the square roots of 2 and 3, the mean diffusates also approach pretty closely.

*Bicarbonates of Potash, Ammonia and Soda.*—Time of diffusion 8·083 days, or double that of hydrate of potash. The water of the jars was partially charged with carbonic acid gas, to prevent the decomposition of the bicarbonates in the act of diffusion.

Diffusion of bicarbonate of potash in 8·08 days at 68°·2; two cells :—

	Grs.	Ratio.
From 1 per cent. solution . . . . .	7·23	1·029
From 2 per cent. solution . . . . .	14·05	2
From 4 per cent. solution . . . . .	26·72	3·806
From 8 per cent. solution . . . . .	52·01	7·408

Diffusion of bicarbonate of ammonia in 8·08 days at 68°·2; two cells :—

	Grs.	Ratio.
From 1 per cent. solution . . . . .	6·91	1·013
From 2 per cent. solution . . . . .	13·65	2
From 4 per cent. solution . . . . .	27·00	3·959
From 8 per cent. solution . . . . .	50·10	7·346

The amount and progression of the diffusion of this salt correspond well, for all the proportions diffused, with the preceding isomorphous bicarbonate of potash.

Diffusion of bicarbonate of soda in 9·87 days at 68°·1; two cells :—

	Grs.	Ratio.
From 1 per cent. solution . . . . .	7·31	1·059
From 2 per cent. solution . . . . .	13·81	2
From 4 per cent. solution . . . . .	26·70	3·869
From 8 per cent. solution . . . . .	52·38	7·590

A remarkable approach to equality in the diffusion of the bicarbonates of potash and soda, in the times chosen, is observed equally in all the proportions of salt from 1 to 8 per cent.

The times chosen for the bicarbonates of potash and ammonia is to that of the bicarbonate of soda, as the square root of 2 to the square root of 3, and the remarkable agreement observed in the diffusion of these salts gives support therefore to that relation. In alluding to this relation, it is, however, added that the carbonates of potash and soda deviate from it in a sensible degree, and the hydrates of potash and soda very considerably; so that if the relation has a real foundation, it must be masked in the salts last named by

differences existing between them in certain properties, the discovery and investigation of which is of the last importance for the theory of liquid diffusion.

*Hydrochlorates of Morphine and Strychnine.*—Time of diffusion 11·43 days. The quantity diffused was determined from the chlorine, which was precipitated as chloride of silver in an acid solution.

These two analogous salts appear to approach very closely in diffusibility.

Diffusion from 2 per cent. solutions at 64°1; two cells :—

Hydrochlorate of morphine. . . . .	11·60	100
Hydrochlorate of strychnine . . . .	11·49	99·05

The diffusion of these salts of organic bases in 11·43 days, is exceeded by the diffusion of chloride of ammonium or potassium in 5·71 days, or half the former time. The vegeto-alkalies appear thus to be divided from ammonia and potash.

## 12. "On the Mutual Relations of the Vital and Physical Forces." By William B. Carpenter, M.D., F.R.S. &c.

The purpose of the author in this communication is to show that the same kinds of "Correlation" as has been pointed out by Prof. Grove to exist among the physical forces,—light, heat, electricity, magnetism, chemical affinity, and mechanical motion,—exists also between these forces and those which operate in the development of living beings, and in the production of all their vital actions.

1. In some introductory remarks, the author briefly recapitulates the leading ideas which have been entertained by physiologists with respect to the relations between the physical and vital forces; and states it to be the doctrine at present in vogue, that vital forces are the manifestations of the dormant properties of organized structures, called into activity by the physical forces which operate as *stimuli*.

2. He then examines into the mutual relations of the several vital forces; and adduces facts and arguments to prove that the forces of assimilation, organization, chemico-vital transformation, and histological transformation, which are concerned in the development and maintenance of living organisms, are so many *modes* of one and the same vital force, whose most general operation is seen in *cell-formation*. And he then goes on to show that the production of the nervous and muscular forces, and of ciliary movement, are due to the same agency. Lastly, he points out that the nervous force, originating in one act of cell-formation, can in its turn influence other acts of the same kind, and can thus modify every other kind of vital operation. Whence he concludes that all these vital forces are "correlated."

3. The author then investigates the relations of the vital and physical forces to each other. Taking the nervous force as the most characteristic example of the former, he shows that it is correlated to electricity, heat, light, chemical affinity, and mechanical motion. He then endeavours to prove that the same correlation exists between *heat* and the organizing forces; so that the latter may be con-